

TEST OF A HARRINGTON
CHAIN GRATE STOKER

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Performance and efficiency
test of a Harrington chain

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PERFORMANCE AND EFFICIENCY TEST OF A HARRINGTON CHAIN GRATE STOKER

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

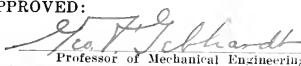
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A HARRINGTON CHAIN GRATE STOKER.

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PART ONE.

Which includes a preliminary discussion and outline of the subject matter, the purpose of the work, the method of procedure, and the final results.

Performance and Efficiency Test of a Harrington Chain Grate Stoker.

Introduction.

Until recently the efficiency of our American power plants has been of secondary consideration. With the once vast beds of coal, slowly but inevitably being exhausted, and the consequent steady increase in fuel cost, this question of economy and boiler efficiency is now paramount in modern plants.

One of the great losses in the conversion of heat to either mechanical or electrical energy is in the boiler. Subdividing the boiler losses, and excluding those which are inherent and caused by radiation, the governing efficiency factor is the boiler setting, which includes the combustion chamber and the grate.

There are few engineering problems which contain more variables than does the one of proper combustion under a steam boiler. However, as all these are common knowledge no space will be devoted here to a further discussion. Suffice to say that a correctly

designed grate in a proper setting is the first step towards higher boiler efficiency. In all the larger installations some form of mechanical stoker is used and with few exceptions is integral with the grate. Perhaps the most common form of stoker, for free burning bituminous coals such as are mined in Illinois, is the chain grate.

Chain Grate Stoker Requirements.

The chain grate consists essentially of an endless linked metallic belt. This belt carries the fuel through the furnace, where it is burned, relieves itself of the refuse and returns to the front of the boiler.

A grate of this type must meet certain definite requirements. There must be enough open space, uniformly distributed over the grate surface, to insure a thorough supply of air to all of the coal. These spaces must be so formed that the sifting of the finer coals through the grate is prevented prior to the combustion of the fuel. The grate must clear

itself of all ash and clinkers. For free burning bituminous coals the fuel must remain undisturbed on the grate surface until combustion is complete. Last, and most important, the grate must be so designed that air leakage around and beneath it is kept at a minimum.

Besides these virtues a grate of this type should possess mechanical improvements such as speed variation, depth of fire regulation, and an accessibility to the various parts.

The Harrington Stoker.

The Grate Surface.

The grate surface proper consists of a series of small castings which match up with one another in such manner that a continuous surface is formed. The air space between adjacent and interlocking bars is dependent upon the size of the bars. The percent air space for any grate, is predetermined dependent upon the kind of fuel to be burned. In assembling the

grate, the clips or bars which will unite to give this air space, are inserted. These grate bars are two inches in width and so designed that they can be slipped over the head of a cast-iron supporting bar or rack, placed transversely to the grate travel. These tracks are bolted to the links of a series of extra heavy semi-steel chains operated through a series of driving sprockets on the front shaft and a set of curved tracks integral with the rear cross girder. Between these two points the chains are supported and guided by steel tracks which engage rollers placed in every link of the chain. The grate surface is entirely self-cleaning, the adjacent sections pulling apart and opening up all air spaces at each turn around the ends.

The Chain Tension.

The chain tension is taken up entirely in the series of semi-steel chains as described above. The bars forming the actual grate surface are free to

expand in any direction and are subjected to no stress whatsoever.

The Grate Bars.

Due to the fact that the grate bars themselves are free and independently carried on grate racks, any bar can be replaced without removing the tension on the chain and without in any way affecting the adjacent bars. Burned or broken bars can be removed while the stoker is under fire.

The Drive.

This stoker may be driven in any one of three ways. First: From a line shaft through a special speed-changing device to a worm wheel in an enclosed housing. Second: From an individual motor attached to the side frame, and driving through a series of enclosed worm gears to the main worm wheel on the front sprocket shaft. Third: By an individual engine attached to the side frame through a similar train of worm gears.

The last mentioned method is the one employed on the stoker from which the thesis tests were taken.

Air Seal.

On the particular unit, which was under observation, the grate was sealed on the fire side by over-hanging ledges of brick extending the full length of the chain on both sides. The clearance between these ledges and the grate surface was made a minimum. The ash pit was sealed at the back of the grate by a swinging door which left small space for leakage between it, and the returning grate surface.

Draft Gear.

The stoker was equipped for either natural or forced draft. Air was admitted to any or all of three equal zones, on the fire side, by means of dampers placed between the fire and return side of the grate.

Vertical baffles, set transversely to the grate travel and between the moving side of the "belt,"

formed the three rectangular zones. In the bottom of these zones, directly above the returning side of the grate, were located the horizontal natural draft dampers. Air found its way to these dampers through the open (front) end of the ash pit. When these dampers were closed "wind boxes" were formed for the forced draft, which was supplied through vertical dampers at one end of each box.

The forced draft was supplied from an engine-driven blower through a duct which connected with the three zone dampers.

The Plant.

The unit tested is located in the power plant of the Armour Institute of Technology, 33rd and Federal streets, Chicago, Illinois. This plant furnishes heat and power to the Institute and a block of apartment buildings. It consists of two 250 H. P. and one 350 H. P. Stirling water tube boilers. The former are equipped with Green Chain Grate Stokers and the latter with the Harrington

Stoker, upon which this test was made.

The combustion chamber in this unit is about 18 ft. high and extends from the first row of tubes to the coking arch which protrudes inward from the front of the boiler about 3 ft. and about the same distance above the normal fuel surface. There are two passes, one down and one up, between the chamber and the breeching.

The breeching is a straight pass from the rear of the setting into the base of the stack. A butterfly damper, controlled hydraulically from the guage board, is located here.

The stack is situated behind this unit. The other boilers unite into an uptake which leads to another side of the stack at a different level. The chimney is constructed of building brick and sets on an octagonal base 16 ft. in diameter. It has a 7 foot internal diameter and is 175 feet high, measured from the boiler room floor.

The auxiliaries used with this boiler are: any or all of three horizontal reciprocating feed pumps, cross connected; open feed heater and condenser; and a single barrel piston air pump. The feed pumps are:

- | | | |
|-----|--------------|----------|
| (1) | Smith Vaile. | Duplex. |
| (2) | Worthington. | Duplex. |
| (3) | American. | Simplex. |

The combination feed heater and condenser is of the old Webster type.

Besides the fittings required by law this unit has several modern appurtenances which, together with the testing apparatus, insured, at least, good relative data.

Diamond soot blowers; a Uehling CO₂ recording apparatus; Builders Iron Foundry venturi meter; Bristol recording feed water thermometer and flue gas pyrometer, and a G. E. steam flow meter compose the extra equipment.

The coal for the plant is delivered in car load lots. The cars are unloaded by hand and the coal sent to the boiler room floor through a chute.

It is shoveled from here into the hopper located in front of the boiler above the stoker.

The ashes are hoed from the pit and then hauled outside.

Purpose of Test.

The object of this work is to present the results obtained and conclusions drawn from a thorough investigation into the performance of a Harrington chain grate stoker installed under a 350 H. P. Stirling boiler in the power plant of the Armour Institute of Technology.

Standard evaporative tests were conducted to determine the efficiency of the boiler and furnace under the conditions existent. The performance and action of the grate in meeting and responding to the fluctuations in load, under which the boiler normally operates, were observed.

Method of Procedure.

In starting every run the boiler was taken over after it had been working several hours under its operating load. Consequently, the conditions were adjusted to be as constant as the variation in the load would permit. The ashes were drawn

and the water level marked on the gage glass. The coal in the hopper was then leveled to a position that was easily duplicated at the end of the run.

These operations were completed just before the time set for starting the run. All coal subsequently fired and all water fed to the boiler, during the run, were weighed. At regular intervals during the test the following observations were made and recorded: steam pressure, temperature of steam in calorimeter, outside temperature, room temperature, feed water temperature, flue gas temperature, draft intensity and flue gas analysis. At the close of the run the water was brought back to the original level; the coal in the hopper to the same position as at starting and the ashes drawn and weighed. A sample of the ashes was taken for analysis. Along with each set of observations the amount of coal fired during the previous interval was noted.

The coal was dumped in the hopper in basket lots of forty pounds. The weight on the scale beam was fixed so that the desired amount of coal

balanced the arm. This phase of the work was done by hand.

From each basket a small amount of coal was taken for a sample. These samples were all placed in another basket. At the end of the run the accumulated sample was spread on the floor, thoroughly mixed, and all lumps broken. It was then quartered and the opposite quarters retained and mixed again. This process was repeated until the sample was about pin-head size and enough to fill a quart fruit jar. The final sample was sealed to prevent moisture loss before a proximate analysis was made.

The sample of coal in the jar was further ground in a mortar and then sifted through a 200 mesh sieve. The coal was then ready for analysis.

The ash sample was taken from the ash pile at the times when they were hauled and treated as was the coal sample.

The volatile combustible in the coal was determined by applying heat, for seven minutes, to a crucible containing the sample. The loss in weight

was taken as the volatile combustible.

The moisture was found by placing a sample of coal in an electric oven, at a temperature of 220 deg. fahr., for one hour.

To determine the ash content the fuel was heated, exposed to the air, until there was no further reduction in weight.

The heating value of the fuel was found in the fuel as fired. A Mahler bomb was used in the usual manner.

The combustible in the ash was found by heating the ash sample until no further reduction in weight was noticed.

Apparatus and its Calibration.

The apparatus used consisted of a scales and a basket for weighing and lifting the coal to the hopper; steam gage; calorimeter for determining the quality of the steam; four thermometers for determining room, outside, feed water and calorimeter temperatures; a venturi meter for measuring the water fed to the boiler; draft gages; revolution counter for grate; pyrometer for obtaining the flue gas temperature and an Orsat apparatus for analysing the flue gas, in addition to the usual apparatus for analysing coal and ash and determining its heat value.

Calibration of Apparatus.

Steam Gage.

The 8 inch Crosby steam gage was tested on a Crosby deadweight machine and after adjustment found to be correct within the limits used on the test (90 - 125 lbs./sq. in.).

Scales.

Two Fairbanks scales were used; one for weighing coal, the other in the calibration of the venturi meter. These were tested and found to be correct by means of standard 50 lb. weights.

Venturi Meter.

Incorrect weights of coal and water are the predominating errors in most boiler tests. The method of weighing coal, as previously described, the authors believe to be as accurate as was consistent with the other observations taken. Due to physical obstructions it was impossible to weigh the feed water. In lieu of this method the venturi meter was used.

It was first over-hauled; all the moving and wearing parts cleaned, oiled, and in some instances parts replaced with new ones. The pipe lines to the venturi tube were then given a drop test and made tight. Rather than attempt to adjust the instrument to read correctly a calibration curve was drawn.

The calibration consisted of several runs at various rates of flow. The water after passing through the tube was bi-passed around the boiler check and weighed in a tank. From the time interval in feeding 1000 lbs. of water in the tank the rate of flow was computed. From this actual flow, and the recorded flow on the meter, points were located on the curve.

A stop watch connected to the scale beam left personal equation out of the start and finish of the run. As noted from the curve the error was consistent. Steam Meter.

The steam flow meter was calibrated with the venturi meter. The readings on the steam meter were averaged for the period of an hour and compared with the reading on the venturi.

The steam flow meter indicates the weight of steam leaving the boiler, and the venturi registers the water entering. By holding the level of the water in the boiler constant the water entering should be the same as that leaving.

The calibration of the steam meter was carried on over two eight hour periods to obtain a fair average.

Carbon Dioxide Recording Apparatus.

The Uehling CO₂ recording apparatus was calibrated by means of an Orsat apparatus. The charge for the Orsat was drawn from a tap in the line leading to the CO₂ recorder in order to obtain as nearly as possible a sample such as was going through the Uehling recorder.

Flue Gas Pyrometer.

The Bristol flue gas pyrometer was calibrated against a standard electric pyrometer (tested by B. of S.) between 300 and 700 degrees Fahr. The terminals of the pyrometer were inserted together in an electric oven and a double set of readings taken; one while the temperature was rising, the other while falling. The instrument was then adjusted so that accurate readings were obtained thereby eliminating a calibration curve.

Thermometers.

The thermometers used were borrowed from the Physics Department of the Armour Institute. They had all been calibrated and their error too small to affect in any way the data taken.

Results and Sample Calculations.

The results of the tests are divided into two parts; the first three runs being conducted with the grate operating under the original setting; and the remaining five with a setting modified to correct some of the faults found to exist.

Changes in Furnace and Grate.

These were two outstanding faults in the original furnace setting; one being the position of the ignition arch, and the other, the action of the forced draft beneath the grate surface.

The general dimensions of the original furnace setting show the position of the arch. There was very little clearance between the arch and top of fuel bed on the grate. According to the accepted theory, the radiant energy of the live fuel is reflected back by the ignition arch upon the green fuel following it, causing the volatile gases to be driven off and leaving the coke. This action was prevented by the proximity of the fuel and arch

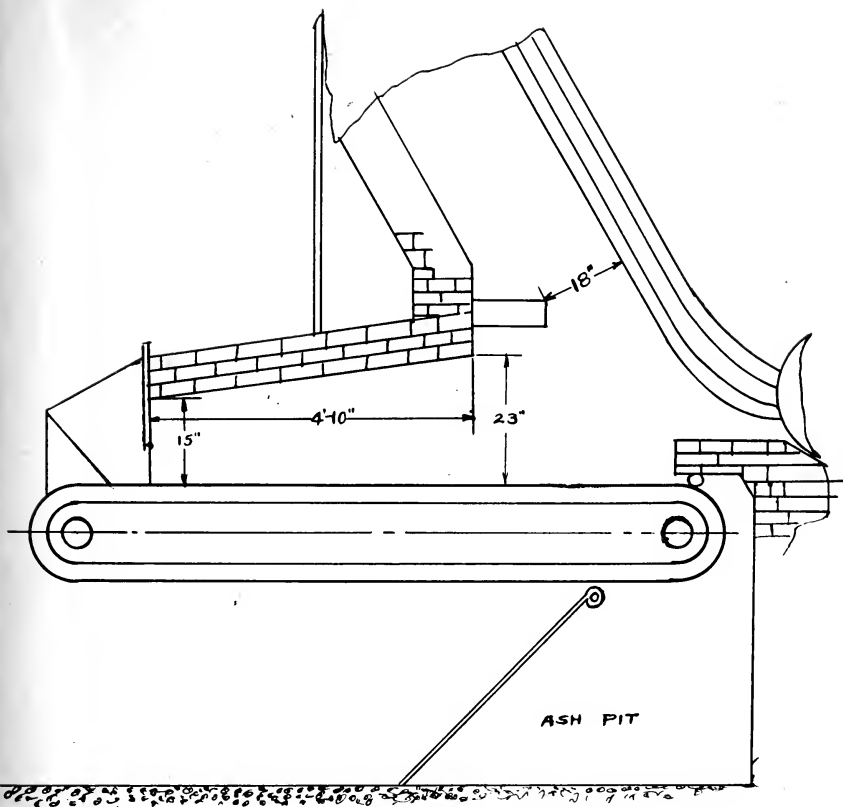


DIAGRAM OF OLD FURNACE SETTING .

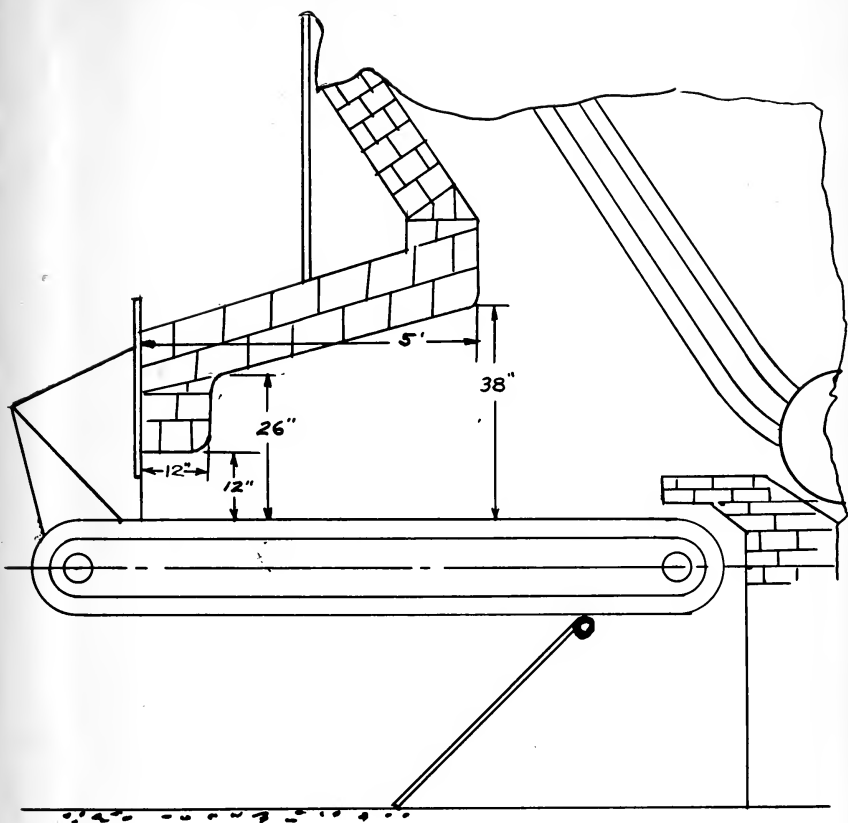


DIAGRAM OF NEW FURNACE SETTING.

and resulted in one-third of the grate being rendered useless for the burning of fuel.

The raising of the arch overcame this defect in the setting construction.

It was impossible to keep an even fire using forced draft. It was necessary to rake coal from the side where the air entered over to the opposite side. Due to the shallowness of the air compartment velocity was imparted to the air causing it to flow to the opposite side of the grate. Vertical baffles placed in the chamber served to break up the current of air and distribute it more evenly as evidenced by the more even burning of the fire.



350 H.P. STERLING BOILER
HARRINGTON CHAIN GRATE.
9FT. LONG 7FT. WIDE 63 SQ. FT. AREA
WATER HEATING SURFACE 3500
RATIO OF HEATING TO GRATE 55.5:1

| RUN NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|-------|-------|-------|--------|--------|--------|--------|-------|
| DURATION OF RUN HOURS | 4 1/2 | 5 | 8 | 5 | 8 1/4 | 8 | 8 | 8 |
| AVERAGE PRESSURES:- | | | | | | | | |
| BAROMETER INS. MERCURY. | 29.60 | 29.60 | 29.59 | 29.58 | 29.16 | 29.06 | 29.84 | 29.80 |
| STEAM GAUGE LB. PER SQ. IN. | 101 | 99.5 | 97.2 | 110.63 | 97.09 | 112.4 | 97.87 | 97.8 |
| ABSOLUTE STEAM PRESSURE LBS PER SQ IN. | 115.5 | 115 | 111.8 | 125.13 | 111.39 | 126.63 | 112.52 | 112.3 |
| DRAUGHT { OVER FIRE INS. WATER | | | | | -.152 | -.146 | -.12 | -.115 |
| { #2 COMPARTMENT INS. WATER | +.055 | +.050 | +.070 | | +.215 | | | |
| { #3 COMPARTMENT INS. WATER | | | | | +.168 | | | |
| AVERAGE TEMPERATURES:- | | | | | | | | |
| EXTERNAL AIR DEG. FAHR. | 31 | 37 | 35 | 50 | 45 | 55 | 56 | 57 |
| BOILER ROOM DEG. FAHR. | 55 | 65 | 57 | 61 | 68 | 75 | 76 | 77 |
| FLUE DEG. FAHR. | 408 | 440 | 420 | 401 | 379 | 409 | 400 | 395 |
| FEED WATER DEG. FAHR. | 180 | 194 | 179.9 | 206 | 178.7 | 204 | 196.7 | 187.0 |
| STEAM DEG. FAHR. | 338.4 | 338.1 | 335.9 | 344.4 | 335.6 | 345.3 | 336.5 | 336.3 |
| TOTAL FUEL | | | | | | | | |
| COAL AS FIRED LBS. | 6060 | 7880 | 9760 | 8120 | 11800 | 12417 | 9520 | 9170 |
| DRY COAL CONSUMED LBS. | 5210 | 6820 | 8979 | 7250 | 10762 | 11050 | 8463 | 8150 |
| TOTAL REFUSE DRY LBS. | 1162 | 1368 | 1550 | 950.5 | 1928 | 1154 | 806 | 827 |
| TOTAL REFUSE DRY PERCENT DRY COAL | 22.3 | 20 | 17.29 | 13.1 | 16.4 | 10.4 | 9.54 | 10.18 |
| COMBUSTIBLE CONSUMED LBS | 4048 | 5452 | 7429 | 6300 | 8834 | 9896 | 7657 | 7323 |
| COMBUSTIBLE CONSUMED PERCENT DRY COAL | 77.5 | 80 | 82.8 | 87 | 75.25 | 88.5 | 90.5 | 89.9 |

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|--|---------|--------|--------|--------|--------|--------|--------|---------|--------|
| FUEL PER HOUR | | | | | | | | | |
| COAL AS FIRED | LBS. | 1484 | 1576 | 1220 | 1624 | 1475 | 1552 | 1190 | 1141 |
| DRY COAL | LBS. | 1275 | 1564 | 1122 | 1450 | 1345 | 1381 | 1058 | 1019 |
| COMBUSTIBLE CONSUMED | LBS. | 990 | 1090 | 928 | 1260 | 1104 | 1237 | 957 | 913 |
| DRY COAL PER SQ. FT. OF GRATE | LBS. | 20.2 | 24.8 | 17.8 | 23 | 21.35 | 20.9 | 16.8 | 16.18 |
| TOTAL WATER | | | | | | | | | |
| QUALITY OF STEAM | PERCENT | 97 | 97.7 | 97 | 96.7 | 96.8 | 97.2 | 97.2 | 97.1 |
| APPARENTLY EVAPORATED | LBS. | 41886 | 54830 | 71268 | 73750 | 95700 | 112800 | 91200 | 85600 |
| ACTUALLY EVAPORATED INTO DRY STEAM | LBS. | 40629 | 53560 | 69124 | 71537 | 92644 | 109641 | 88646 | 83117 |
| FACTOR OF EVAPORATION | | 1.0453 | 1.0366 | 1.0426 | 1.0171 | 1.0440 | 1.0243 | 1.0180 | 1.0386 |
| TOTAL FROM AND AT 212 DEG. | LBS. | 42469 | 55528 | 72068 | 72753 | 96720 | 112305 | 90241 | 86325 |
| WATER PER HOUR. | | | | | | | | | |
| APPARENTLY EVAPORATED | LBS. | 10250 | 10956 | 8908 | 14750 | 11600 | 14100 | 11400 | 10700 |
| ACTUALLY EVAPORATED | LBS. | 9930 | 10713 | 8640 | 14307 | 11200 | 13705 | 11080.7 | 10389 |
| EVAPORATED FROM AND AT 212 DEG. FAHR. | LBS. | 10400 | 11105 | 9008 | 14550 | 11720 | 14038 | 11280.1 | 10790 |
| EVAPOPOPORATION | | | | | | | | | |
| PER POUND OF FUEL AS FIRED | | | | | | | | | |
| APPARENT | LBS. | 6.91 | 6.95 | 7.29 | 9.09 | 8.11 | 9.06 | 9.58 | 9.34 |
| ACTUAL | LBS. | 6.70 | 6.80 | 7.08 | 8.80 | 7.85 | 8.81 | 9.21 | 9.06 |
| EQUIVALENT FROM AND AT 212 DEG. | LBS. | 7.00 | 7.05 | 7.38 | 8.95 | 8.20 | 9.05 | 9.49 | 9.40 |
| PER POUND OF DRY COAL | | | | | | | | | |
| APPARENT | LBS. | 8.03 | 8.04 | 7.94 | 10.17 | 8.90 | 10.20 | 10.79 | 10.51 |
| ACTUAL | LBS. | 7.79 | 7.85 | 7.07 | 9.85 | 8.60 | 9.91 | 10.46 | 10.20 |
| EQUIVANT FROM AND AT 212 DEG. | LBS. | 8.15 | 8.15 | 8.03 | 10.02 | 8.99 | 10.15 | 10.65 | 10.60 |
| PER POUND OF COMBUSTIBE CONSUMED | | | | | | | | | |
| APPARENT | LBS. | 10.35 | 10.05 | 9.59 | 11.70 | 10.82 | 11.40 | 11.90 | 11.69 |
| ACTUAL | LBS. | 10.03 | 9.80 | 9.30 | 11.35 | 10.50 | 11.10 | 11.58 | 11.35 |
| EQUIVALENT FROM AND AT 212 DEG. | LBS. | 10.49 | 10.19 | 9.70 | 11.55 | 10.95 | 11.39 | 11.8 | 11.79 |
| PER SQ. FOOT OF HEATING SURFACE PER HOUR | | | | | | | | | |
| ACTUAL | LBS. | 284 | 306 | 246 | 408 | 3.21 | 392 | 318 | 2.96 |
| EQUIVALENT FROM AND AT 212 DEG. | LBS. | 2.975 | 3.17 | 2.57 | 4.15 | 3.35 | 4.01 | 3.22 | 3.08 |

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|--------------------------------------|---------------|-------|-------|-------|-------|-------|----------|----------|----------|
| HORSE POWER | | | | | | | | | |
| ON BASIS 34 1/2 LB. EQUIV. EVAP. PER | | | | | | | | | |
| HOUR | H.P. | 301 | 322 | 261 | 420 | 340 | 407 | 371 | 312.5 |
| COMMERCIAL BUILDERS RATING | | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 |
| PERCENT OF BUILDERS RATING | | 85.5 | 92 | 74.5 | 120 | 97.2 | 116 | 106 | 88.4 |
| EFFICIENCY OF BOILER AND GRATE | | 60.5 | 58.3 | 61.5 | 70.6 | 72.5 | 70.2 | 73.5 | 72.9 |
| ANALYSIS | | | | | | | | | |
| ANALYSIS OF FUEL AS FIRED | | | | | | | | | |
| FIXED CARBON | PER CENT | 48.79 | 53.5 | 55.5 | 46.9 | 49.95 | | | 55.6 |
| VOLATILE MATTER | PER CENT | 23.48 | 25.00 | 23.50 | 28.50 | 24.60 | | | 25.0 |
| MOISTURE | PER CENT | 14.23 | 8.00 | 8.00 | 8.25 | 8.80 | 11.1 | 11.1 | 8.3 |
| ASH | PER CENT | 13.50 | 13.50 | 13.50 | 16.35 | 16.65 | | | 11.1 |
| COMBUSTIBLE | PER CENT | 72.27 | 78.5 | 78.5 | 75.40 | 74.55 | | | 80.6 |
| CALORIFIC VALUE OF FUEL AS FIRED | | | | | | | | | |
| | B.T.U. | 11256 | 11730 | 11640 | 12200 | 10980 | 12500 | 12500 | 12500 |
| ANALYSIS OF FLUE GAS | | | | | | | | | |
| CO ₂ | PER CENT | 7.80 | 7.76 | 7.66 | 9.84 | 7.75 | 8.87 | 7.34 | 7.88 |
| CO | PER CENT | | | | | | | .40 | .40 |
| O ₂ | PER CENT | | | | | | | 10.76 | 10.12 |
| DEPTH OF FIRE | INS. | 7" | 6 | 6 | 7 | 7 | 6 1/2 | 6 | 5 |
| SPEED OF GRATE | INS. PER MIN. | 2.074 | 2.203 | 1.765 | | | 2.01 | 1.95 | 1.165 |
| POSITION OF DAMPER | | WIDE | WIDE | WIDE | WIDE | WIDE | 3/8 OPEN | 1/2 OPEN | 3/8 OPEN |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Sample Calculations

April 15, 1920.

| | |
|-----------------------------------|--------------|
| Duration of Run | 8.25 hours |
| Grate Surface | 63 sq. ft. |
| Water Heating Surface | 3500 sq. ft. |
| Ratio of heating to Grate Surface | 55.5 to 1 |

Average Pressures.

| | |
|-------------|-------------------|
| Barometer | 29.16 ins. Hg. |
| Steam Gauge | 97.09 lbs./sq.in. |

Absolute Steam Pressure:-

$$\frac{29.16 \times 13.6 \times 62.5}{12 \times 144} = 14.3 \text{ lbs. per sq. in.}$$

13.6 = density of mercury

62.5 = wt. of cu. ft. of water

$$97.09 + 14.3 = 111.39 \text{ lbs./sq.in.}$$

Average Temperatures

| | |
|--------------|---------------|
| External air | 45 deg. F. |
| Boiler Room | 68 deg. F. |
| Flue | 379 deg. F. |
| Feed Water | 178.7 deg. F. |

Total Fuel.

Coal as Fired 11800 lbs.

Dry Coal Consumed:-

$$\frac{11,800 \times (100 - 8.8)}{100} = 10,762 \text{ lbs.}$$

8.8 moisture per cent

Total Refuse, dry 1,928 lbs.

Total Refuse, dry (per cent of dry coal)

$$\frac{1928}{10762} \times 100 = 16.4\%$$

Combustible Consumed:-

$$10762 - 1928 = 8834 \text{ lbs.}$$

Combustible Consumed (per cent of dry coal):-

$$\frac{8834}{10762} \times 100 = 75.25\%$$

Fuel Consumed per Hour.

Coal as Fired:-

$$\frac{11,800}{8.25} = 1475 \text{ lbs.}$$

Dry Coal:-

$$\frac{10,762}{8.25} \quad 1345 \text{ lbs.}$$

Combustible Consumed:-

$$\frac{8834}{8.25} \quad 1104 \text{ lbs.}$$

Dry Coal per sq. foot of Grate

$$\frac{1345}{63} \quad 21.35 \text{ lbs.}$$

Total Water.

Quality of Steam:- 96.8%

$$x, r_1 + q_1 = x_2 r_2 + q_2 + c_p t_s \quad x_2 = 1.0$$

$$x_1 = \frac{r_2 - q_1 + q_2 + c_p t}{r_1} \quad \text{at } 14.3 \text{ lb./sq.in. :-}$$

Substituting in the above,

$$x_1 = .968$$

$$r_2 = 970.4$$

$$q_2 = 180$$

$$c_p = .48$$

$$t_s = 233 - 212 \quad 21 \text{ deg.F.}$$

$$t_s = 21$$

233 deg.F. was average

at 119.39 lbs./sq.in. :-

temperature of steam in

$$r_1 = 881.9$$

calorimeter.

$$q_1 = 306.2$$

Apparently Evaporated.

| | |
|-------------------------------------|----------------|
| Venturi at start of run | 509,145.0 lbs. |
| Venturi at close of run | 509,230.5 lbs. |
| Water used during run | 85,500 lbs. |
| Water per hour $\frac{85500}{8.25}$ | 10,350 lbs. |

Corrected 11,600 lbs.

11,600 X 8.25 95,700 lbs.

Actually Evaporated into Dry Steam:-

95,700 X .968 92,644 lbs.

Factor of Evaporation:-

$$f = \frac{x, r, + q_1 - q_2}{970.4} \quad x, = 96.8$$

at 111.39#/sq.in. :-

$$f = 1.0440 \quad r, = 881.9$$

$$q_1 = 306.2$$

$$q_2 = 178.7 - 32 = 146.7$$

Total from and at 212 deg. F.

92644 x 1.0440 96,720 lbs.

Water per hour apparently evaporated:-

$$\begin{array}{r} 95700 \\ \hline 8.25 \end{array} \quad 11,600 \text{ lbs.}$$

Evaporation per pound of Coal as Fired,
Equivalent from and at 212 deg. F. :-

$$\begin{array}{r} 96720 \\ \hline 11800 \end{array} \quad 8.20 \text{ lbs.}$$

Per Pound of Dry Coal,

Equivalent from and at 212 deg. F. :-

$$\begin{array}{r} 96720 \\ \hline 10762 \end{array} \quad 8.99 \text{ lbs.}$$

Per Pound of Combustible Consumed,

Equivalent from and at 212 deg. F. :-

$$\begin{array}{r} 96720 \\ \hline 8834 \end{array} \quad 10.95 \text{ lbs.}$$

Per Square Foot of Water Heating Surface per Hour,

Equivalent from and at 212 deg. F. :-

$$\begin{array}{r} 11720 \\ \hline 3500 \end{array} \quad 3.35 \text{ lbs.}$$

Horse Power.

On basis of 34.5 lb. equivalent evaporation per hour:-

$$\frac{11720}{34.5} \quad 340 \text{ B.H.P.}$$

Ratio of Commercial to Builder's Rating:-

$$\frac{340}{350} \times 100 \quad 97.2\%$$

Efficiency:-

$$\frac{8.20 \times 970.4}{10,980} \times 100 \quad 72.5\%$$



ACTUAL
WEIGHT
IN
1000 LB.

VENTURI METER
CALIBRATION CURVE

20

19

18

17

16

15

14

13

12

11

10

10

11

12

13

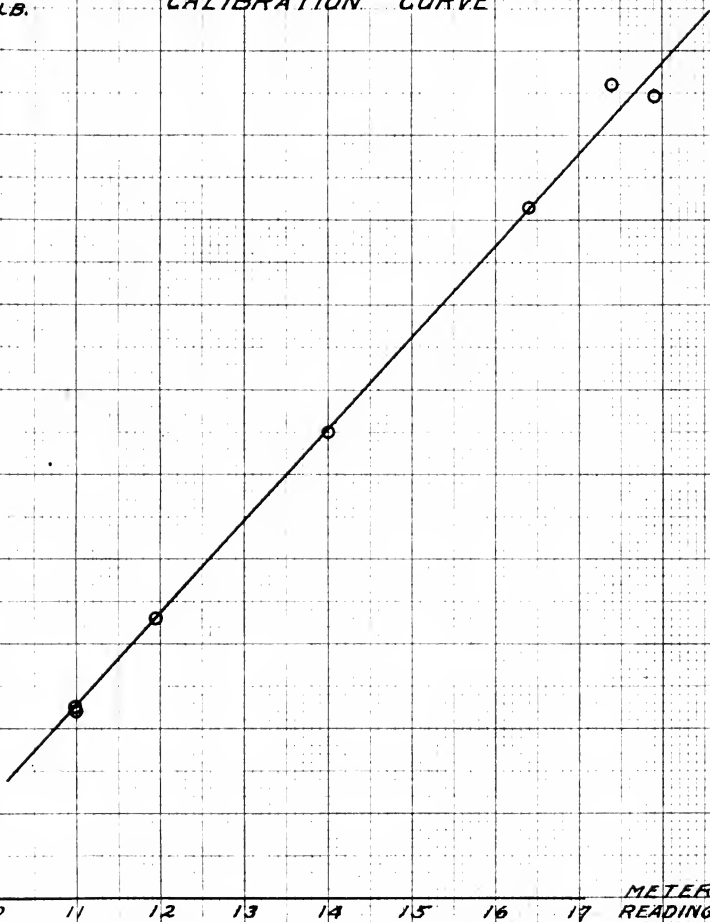
14

15

16

17

METER
READING
IN
1000 LB.





EFFICIENCY - CAPACITY CURVE

PER CENT
EFFICIENCY

74

72

70

PER CENT
OF RATING

120

115

110

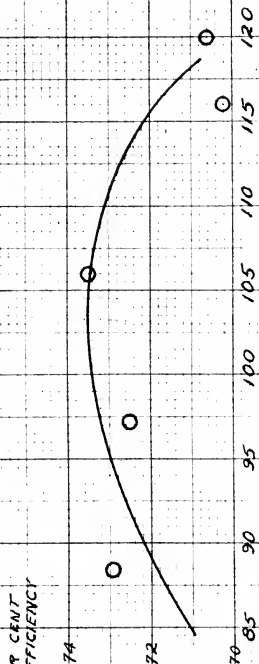
105

100

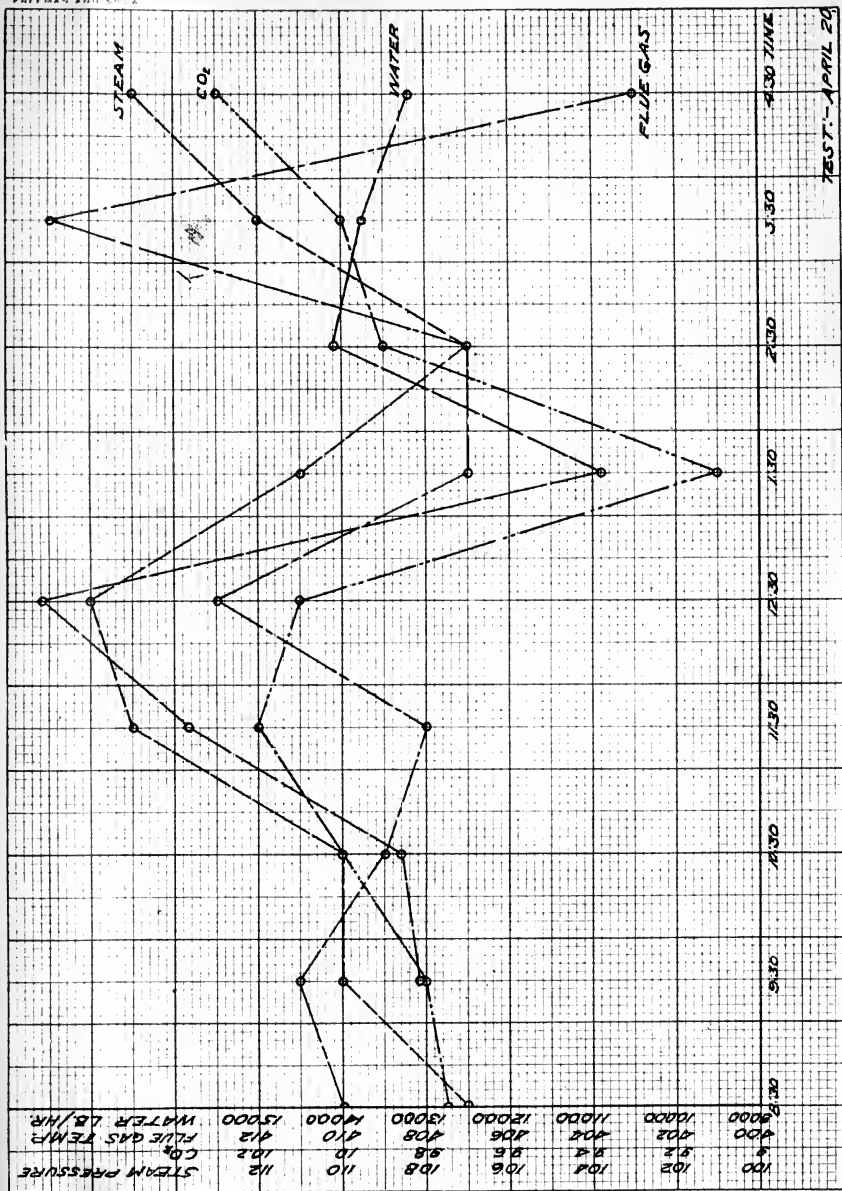
95

90

85

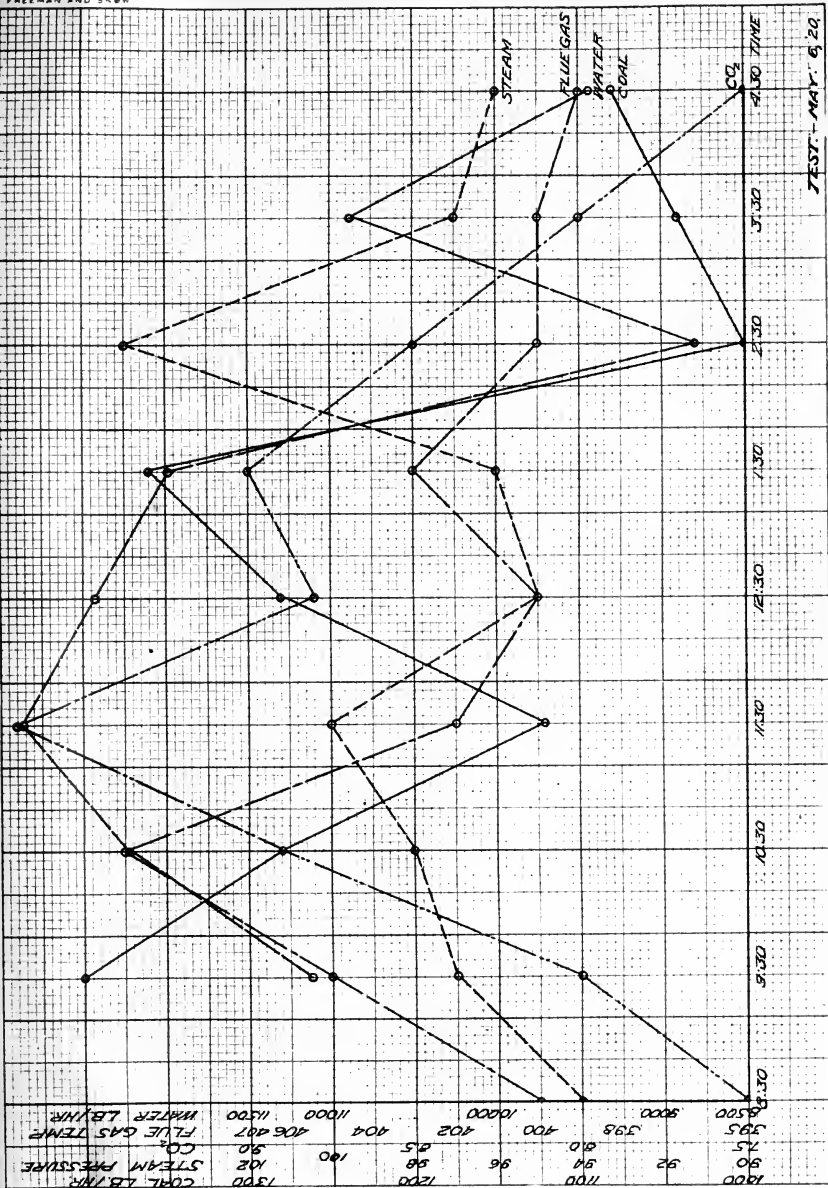






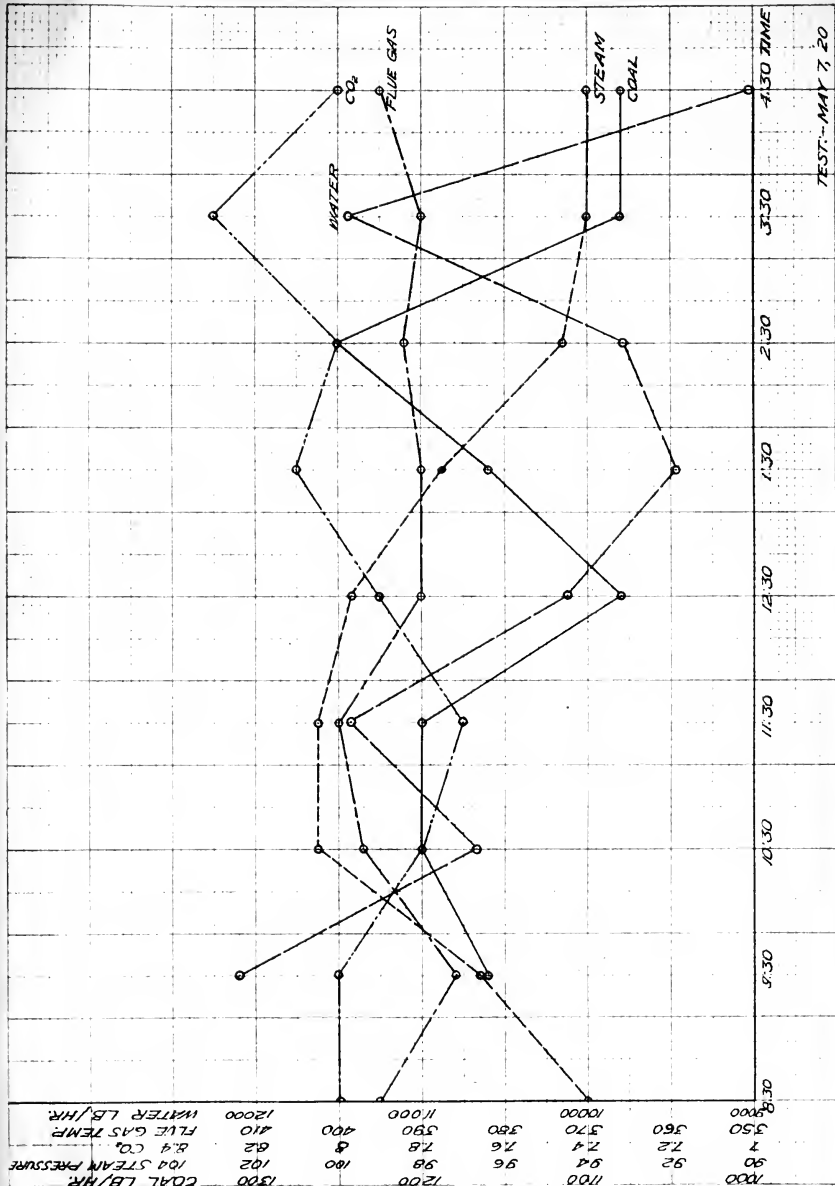
TEST: - APRIL 20





TEST - MAY 6, 20



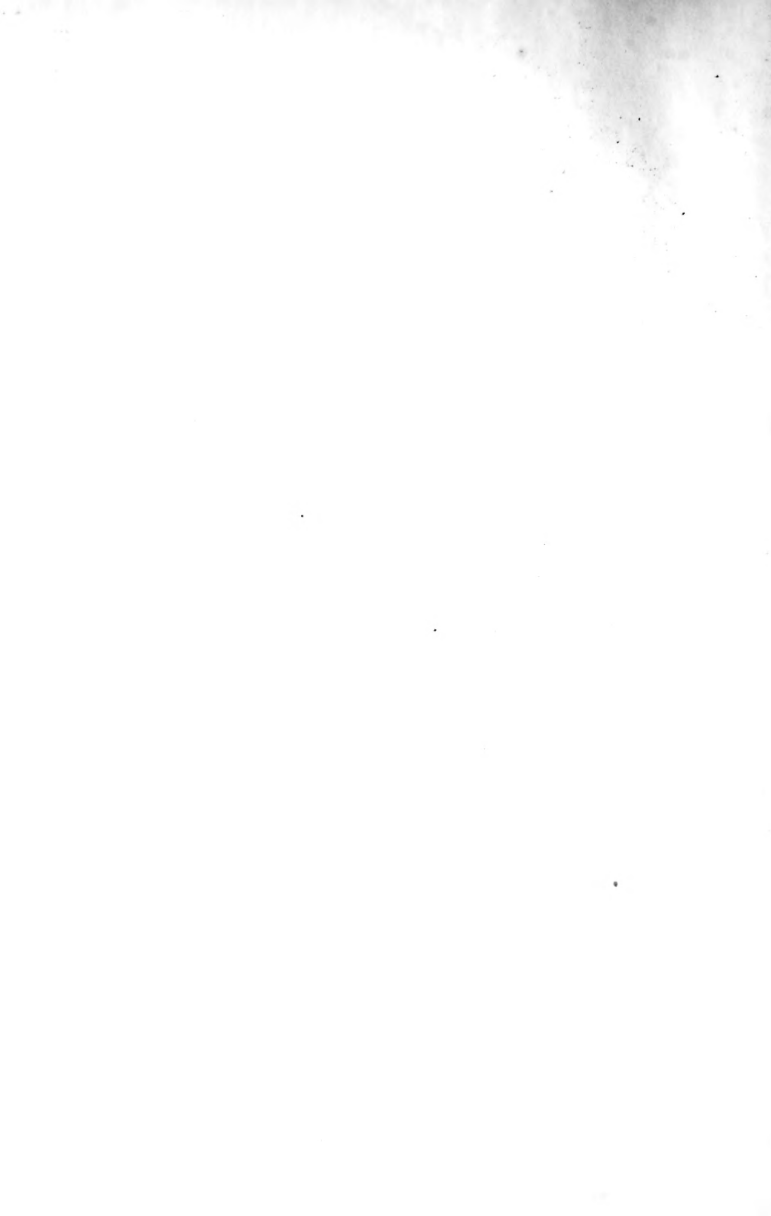


TEST - MAY 7, 20



PART TWO.

Which contains the conclusions as deduced
from the results.



Conclusions.

In presenting these conclusions the authors are merely setting forth their opinions, which are by no means incontestible.

At the times when tests were conducted the entire load of the plant was thrown on the unit under observation. The great fluctuations in load (as noted by steam meter readings), and the slight variation in steam pressure shows the grate adaptable to such conditions. (In the data the steam pressure has considerable variation in the first five runs. This was due entirely to the coal. The grate was designed to handle #3 wash nut (Illinois) and during the last three runs this was used. However, because of the impending fuel famine, at the time the first five runs were made it was necessary to burn screenings, which ran so low in heat value that the maximum speed of grate and intensity of draft would not maintain the desired working pressure).

Mechanically the grate is very satisfactory. Its flexibility to meet large fluctuations in load has already been mentioned. The changing of grate bars is a very simple operation and was performed by the authors with the grate under fire. No trouble was encountered with clinkers, and the sifting of the finer fuels through to the ash pit was negligible.

The most prominent defect evidenced in the operation of this unit was the low carbon dioxide content in the flue-gas. Despite the great attention given the draft, its intensity and distribution, the highest individual CO_2 content recorded was ten per cent.

The changes made on the setting resulted in an increase of from sixty percent on the old setting to seventy-two on the new, over all efficiency. At the time these changes were made an inspection of the combustion chamber, side walls, passes and breeching was made. The brick work throughout the boiler setting, including the main baffles, was found to be intact and practically air tight. However, despite



the most careful manipulation of the various dampers there was at all times an excess of air. As the ash pit door shut off all air supply to the back of the grate, the only remaining entrances left for the air to reach the flue was through, around and between the moving sides of the grate. Although no holes large enough to be seen were left uncovered, the authors feel that there was a leakage through the grate and green coal due possibly to the peculiar design of the bars.

The raising of the coking-arch had no appreciable effect upon the CO_2 content. The increase in efficiency was gained by completing combustion in the earlier passes as evidenced by the decrease in flue-gas temperature (440-400 deg. F.). Due to the force of circumstances the last few runs were conducted at a low rating. The fire covered only about one-third to one-half of the grate. Under these conditions the CO_2 ran between 7.5 percent and 7.8 percent.

It may be that the forced draft air, which passes into the "wind-boxes" and carries itself to the opposite side of the grate due to its kinetic energy, partially by-passes itself around the live fuel at the grate's side. Improvised vertical baffles set in the center of the "wind-boxes" converted part of this kinetic energy into velocity upwards through the fire and perhaps a scientific arrangement of such baffles would entirely eliminate this difficulty.

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